DEVELOPMENT OF THE NISSAN ASV-2

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ABSTRACT

This paper describes the Nissan ASV-2, an experimental advanced safety vehicle, and the technologies incorporated in this vehicle. The Nissan ASV-2 was developed during the second phase (FY 1996-2000) of the Advanced Safety Vehicle (ASV) program promoted by the Ministry of Land, Infrastructure and Transport. Newly developed technologies are incorporated into the vehicle specifically for reducing the number of traffic accidents overall. Overviews are given of the major individual systems that have been developed as Nissan ASV technologies, and several systems that are distinctive features of the ASV-2 are discussed in detail.

INTRODUCTION

The second phase of the Advanced Safety Vehicle (ASV) program was promoted by the Ministry of Land, Infrastructure and Transport from FY 1996 to FY 2000, following the completion of the first phase (FY 1991–1995). The second phase of the ASV program saw the development of the Nissan ASV-2, an experimental advanced safety vehicle like the Nissan ASV that was created in the first phase. This Nissan ASV-2 took part in "Demo 2000", a demonstration of Intelligent Transport Systems (ITS) in Japan last year, showcasing its onboard technologies to the participants in this event.

With the aim of reducing traffic accidents, we have developed a number of new ASV technologies classified into seven categories, i.e., supporting recognition and judgment by drivers, reducing the driver's workload, accident avoidance, passive safety, pedestrian protection, cooperative interaction with the road infrastructure and fundamental automotive technologies. Among our new ASV technologies, more than twenty ASV systems are incorporated in the Nissan ASV-2. The names of these systems embodying new technologies are listed below.

The rest of the paper is organized as follows. First, overviews of the major systems that represent Nissan ASV technologies in each category are given. Then, several systems that were experienced by participants of "Demo 2000" are shown in detail. Conclusion and future works are remarked at last.

Figure 1. NISSAN ASV-2

1. Technologies for supporting recognition and judgment by drivers
- Drowsy/inattentive driving warning system
- High-functionality taillamp system
- Headlamps with adaptive illumination pattern control
- Super-aqua-slick coating for windshield and side windows
2. Technologies for reducing the driver's workload
- Lane-keeping support system
- All-speed-range ACC system with automatic brake actuation for reducing collision speed
3. Accident avoidance technologies
- Automatic braking system for reducing collision speed
- Active brake control system for emergency maneuvering
4. Passive safety technologies
- Collision detection-based retraction advisory seatbelt restraint system
5. Technologies for pedestrian protection
- Vehicle body and airbags for pedestrian protection
- Pedestrian warning & automatic braking system for reducing collision speed
- Blind spot pedestrian warning system

CCD Camera for taking facial images

Alert driving

Detection of drowsiness
(Recognition of eye closure)

Detection of inattention
(No eye or eyebrow data)

Figure 2. Drowsy/inattentive driving warning system

6. Technologies using information from the road infrastructure
- Support system for preventing collisions with forward obstacles
- Support system for prevention of overshooting on curves
- Support system for preventing lane departure
- Support system for prevention of broadside collisions at intersections
- Support system for preventing right-turn collisions
- Support system for preventing collisions with pedestrians in crosswalks
- Support system for using road surface condition information to maintain headway distance

7. Fundamental automotive technologies
- Drive recorder for basic R&D work
- Silent visual mobile phone

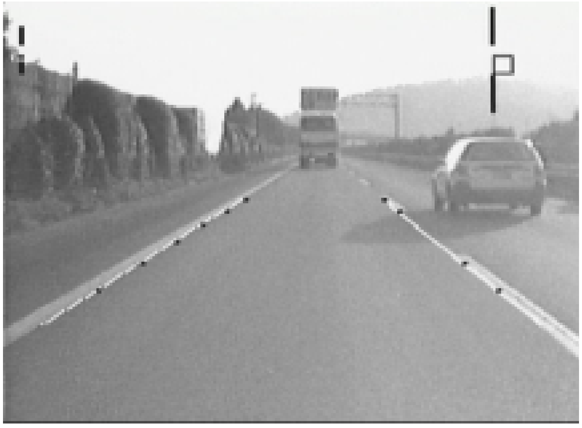
DEVELOPMENT CONCEPT OF THE NISSAN ASV-2

At Nissan, we have been working on a project to cut the number of serious injury accidents in half, the basic concept of which is a unique "triple safety" philosophy derived from an analysis of the process in which traffic accidents occur. Triple safety comprises three citadels or principles of safety. The first is "information safety" for forewarning the driver of potential danger. The second is "control safety" for assisting the driver in avoiding potential danger. The third is "impact safety" for helping reduce injury in the event of an accident.

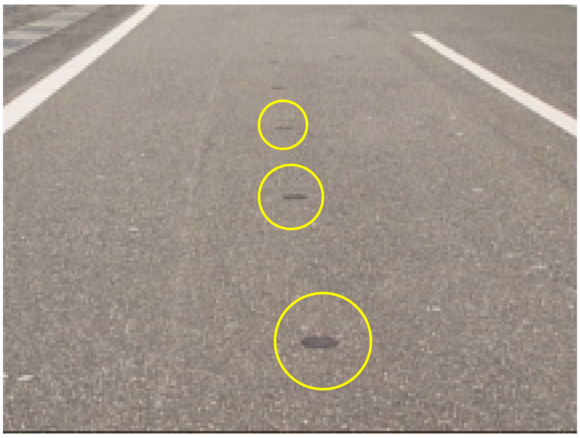
At the beginning of the development work on the Nissan ASV-2, two concepts were defined for reducing the number of traffic accidents overall, in addition to previously developed safety features for cutting in half the number of serious injury accidents. One of these concepts is aimed at reducing the number of traffic accidents and the other concept is aimed at protecting pedestrians, representing vulnerable road users. New technologies for cooperative interaction with the road infrastructure as well as new autonomous systems were developed on the basis of these two concepts.

EXAMPLES OF MAJOR NISSAN ASV TECHNOLOGIES

Technologies for supporting recognition and judgment by drivers



White lane line detection by CCD camera



Magnetic lane markers on the road

Figure 3. Lane-keeping support system

Drowsy/inattentive driving warning system - The system warns the driver of drowsiness or inattention based on facial images analyzed by an image processing technique. In addition to a drowsy driving warning function, an inattentive driving warning function has been newly added. For inattentive driving, the detected eye position is used to judge whether the eyes are where they should be for normal vehicle operation. A warning is issued if an inattentive state is detected where the driver's face is obviously turned away from the road ahead.

Technologies for reducing the driver's workload

Lane-keeping support system - The system is aimed at reducing the driver's workload by supporting lane-keeping steering action, primarily in expressway driving. By processing the images taken by a CCD camera, the system recognizes the host vehicle's lateral position in its lane and assists the driver's steering effort so that the vehicle constantly stays in the middle of the lane. In addition to this autonomous control system commercialized this year, capability for cooperative control with the infrastructure has been added. On a road provided with magnetic lane markers, the system detects magnetic signals using an onboard detector. This enables the system to recognize the host vehicle's lateral position in its lane and allows the driver easily to keep the vehicle in its lane based on that information. When the host vehicle enters an area where such service is available, this capability for cooperative control with the infrastructure is automatically activated and a smooth transition is made from the autonomous control system.

Accident avoidance technologies

Active brake control system for emergency maneuvering - The system optimizes the braking force at each wheel and comprehensively controls

ACC driving

Stop-and-go driving

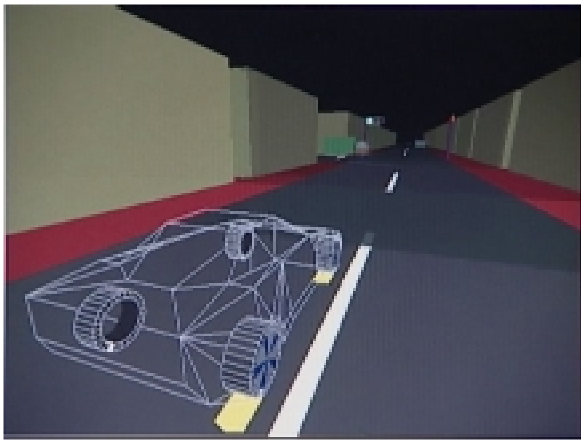
Figure 4. All-speed-range ACC system with automatic brake actuation for reducing collision speed

vehicle behavior. When the driver steers to avoid an unexpected obstacle, the system actively controls the braking force at each wheel according to the vehicle state and the state of the obstacle detected by external world sensing devices such as a radar unit. This control system improves the vehicle's turning capability so as to avoid the object. Moreover, the system continues optimum control of the braking force to stabilize vehicle behavior. These control actions assist the driver in executing emergency avoidance maneuvers.

Automatic braking system for reducing collision speed - The system automatically brakes and stops the host vehicle or reduces the collision speed as much as possible in the event the driver is slow to brake or does not brake sufficiently in relation to an obstacle ahead, such as a stopped vehicle.

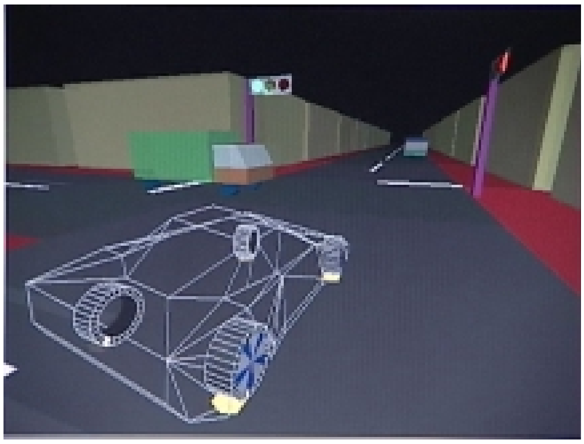
Passive safety technology

Collision detection-based retraction advisory seatbelt restraint system - The system alerts the driver to a potential risk as well as improving occupant restraint performance in an actual emergency. When the system detects an obstacle ahead of the host vehicle such as a stopped vehicle, the seatbelts are automatically retracted as a warning to the driver. If a collision with the obstacle is judged



Track test **Simulation**

Maneuvering: improvement turning capability



Track test **Simulation**

After maneuvering: improvement stability

Figure 5. Active brake control system for emergency maneuvering

unavoidable, the seatbelts are retracted further to assure occupant restraint performance in the subsequent impact.

Technologies for pedestrian protection

Pedestrian warning & automatic braking system for reducing collision speed - In the event of a potential collision with a pedestrian in front of the host vehicle, the system triggers a warning to alert the driver to be careful. If the driver is slow to brake, the system automatically actuates the brakes to reduce the impact speed as much as possible so as to mitigate injury to the pedestrian.

Technologies using information from the road infrastructure

Support system for using road surface condition information to maintain headway distance – The system provides information on road surface conditions based on information from the road infrastructure, prompting the driver to be careful. When cruising under adaptive cruise control, the system maintains an appropriate distance to a preceding vehicle according to the road surface conditions.

Figure 6. Pedestrian warning & automatic braking system for reducing collision speed

Figure 7. Support system for using road surface condition information; advising the driver on a wet road surface ahead

Fundamental automotive technologies

<u>Drive recorder for basic R&D work</u> - The drive recorder is used to record driving data such as the driver's operational inputs, vehicle behavior and images taken by onboard cameras. Data on both accidents and emergency situations (close calls) are analyzed to gain a better understanding of their causal factors and the driver's operational inputs. The results are used in R&D work on safety technologies.

DETAILED EXPLANATION OF ACCIDENT AVOIDANCE TECHNOLOGIES INCORPORATED IN THE NISSAN ASV-2

Among the seven technological categories mentioned above, accident avoidance technologies are regarded as being the most effective in reducing traffic accidents. This section explains in detail some of the associated technologies incorporated in the Nissan ASV-2.

Purpose of the system

The major systems coming under the category of accident avoidance technologies incorporated in the Nissan ASV-2 are an automatic braking system for reducing collision speed and an active brake control system for emergency maneuvering. The construction of the two systems takes into account all maneuvering actions by the driver in trying to avoid a collision with an obstacle in front of the host vehicle. Since the two systems basically use the same brake actuator, they are explained here as one system for the sake of simplicity. The system controls the braking force at each wheel so that it corresponds to the entire range of the driver's emergency maneuvering actions with respect to an obstacle, i.e., avoidance by braking, avoidance by steering, avoidance through a combination of steering and braking, and no avoidance action by the driver. Even if the driver does not act to avoid an obstacle, the system automatically brakes to reduce the collision speed as much as possible.

The following explanation illustrates how the system works. Consider a situation where there is an increased risk of a collision with an object in front of the host vehicle, such as a stopped vehicle, on account of human error due to the driver's inattention or misjudgment. When the system detects such a situation, it alerts the driver to the potential danger. Furthermore, if the driver is slow to avoid the obstacle, the system automatically reduces the host vehicle's speed by controlling the brakes in order to lengthen the time to collision with the obstacle ahead. If the driver brakes to decelerate in this case, the driver's operation is basically given first priority. However the system continues to control the brakes if the driver's action does not decelerate the vehicle sufficiently to achieve maximum possible collision avoidance. In another scenario, if the driver steers to avoid the obstacle, the system automatically brakes to reduce the speed of the host vehicle and simultaneously the system actively controls the braking force at each wheel in order to improve the steering response in line with the driver's steering action. This explains how emergency maneuvering is accomplished with the active brake control system.

The difference between this system and a conventional vehicle dynamics control (VDC) system is as follows. A VDC system basically controls the braking force at each wheel to meet the target vehicle behavior after a certain yaw rate or skidding has actually occurred. On the other hand, this new system actively controls the braking force at each wheel before such vehicle behavior appears, based on the driver's steering action and the state of the obstacle detected by external world sensing devices such as a radar unit. In other words, the active brake control system uses feed-forward control with respect to steering actions and a VDC system uses feedback control with respect to vehicle behavior.

System configuration

Figure 8 shows the configuration of the active brake control system incorporated in the Nissan ASV-2, and Figure 9 is a block diagram of the control system. A millimeter-wave radar installed in the grille and a laser radar installed in the front bumper of the vehicle detect a preceding vehicle or a stopped vehicle ahead. The steering and braking actions of the driver are detected by the signals from a steering angle sensor and a brake fluid pressure sensor. Vehicle behavior is calculated based on the signals from a yaw rate sensor, a lateral acceleration sensor and wheel speed sensors. A brake-by-wire actuator using linear solenoid valves and a throttle actuator are activated to control the degree of deceleration and

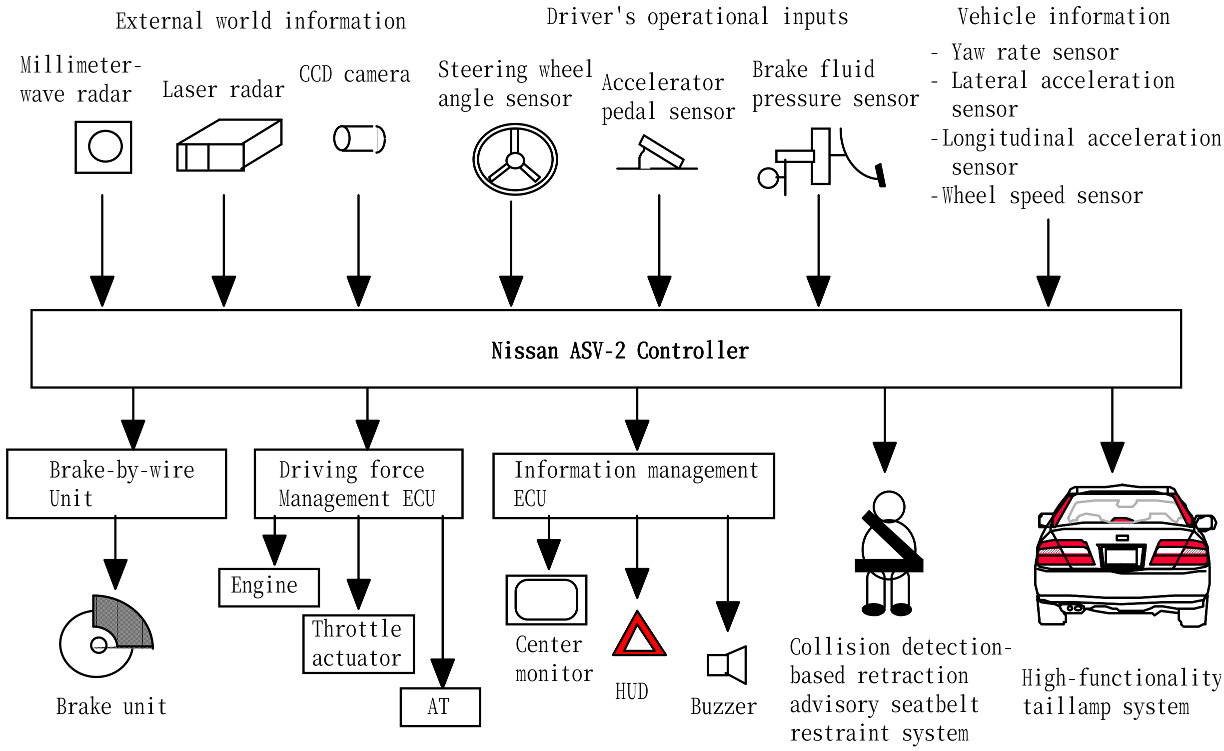


Figure 8. Configuration of an automatic braking system for reducing collision speed and an active brake control system for emergency maneuvering

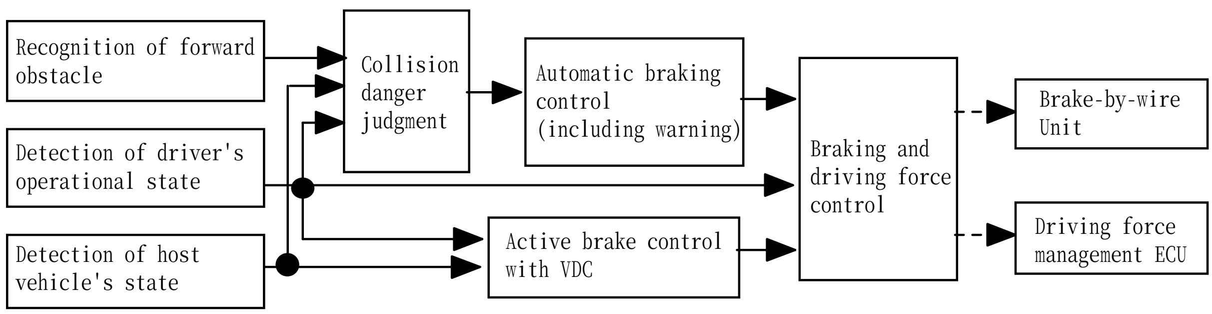


Figure 9. Block diagram of control system

yawing moment of the host vehicle.

Brake control by the new brake-by-wire unit using an actuator with linear solenoid valves includes an automatic braking capability for reducing collision speed and an active brake control function for emergency maneuvering, in addition to conventional functions. The latter include an anti-lock braking system (ABS), a traction control system (TCS), VDC, an electronic braking force distribution (EBD) system, and a brake assist (BA) system.

A combination of these accident avoidance technologies and other Nissan ASV-2 systems is thought to be more effective in reducing the number of traffic accidents than just the application of accident avoidance systems to vehicles alone. For example, consider the combination of the automatic braking system for reducing collision speed and the collision detection-based retraction advisory seatbelt restraint system incorporated in the Nissan ASV-2. When the automatic braking system is activated, the seatbelts are automatically retracted in advance, so that the seatbelts suppress the movement of the occupant’s upper body according to the deceleration resulting from automatic braking and thereby restrain occupants securely in the impact. Another combination consists of the automatic braking system and the high-functionality taillamp system, which are also incorporated in the Nissan ASV-2. When the automatic braking system is activated, the taillamp system flashes the large high-mounted stop lamps to alert following drivers of emergency braking by the automatic braking system.

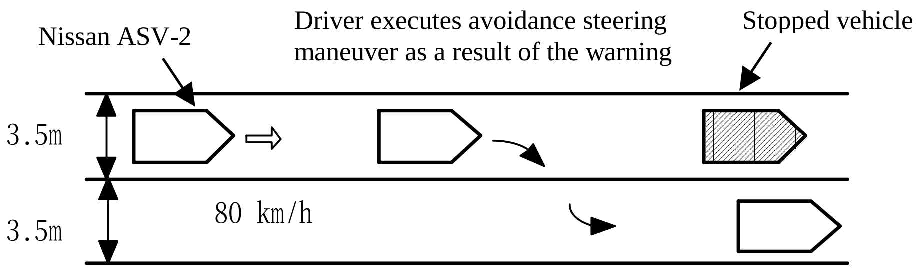


Figure 10. Emergency maneuver experiment

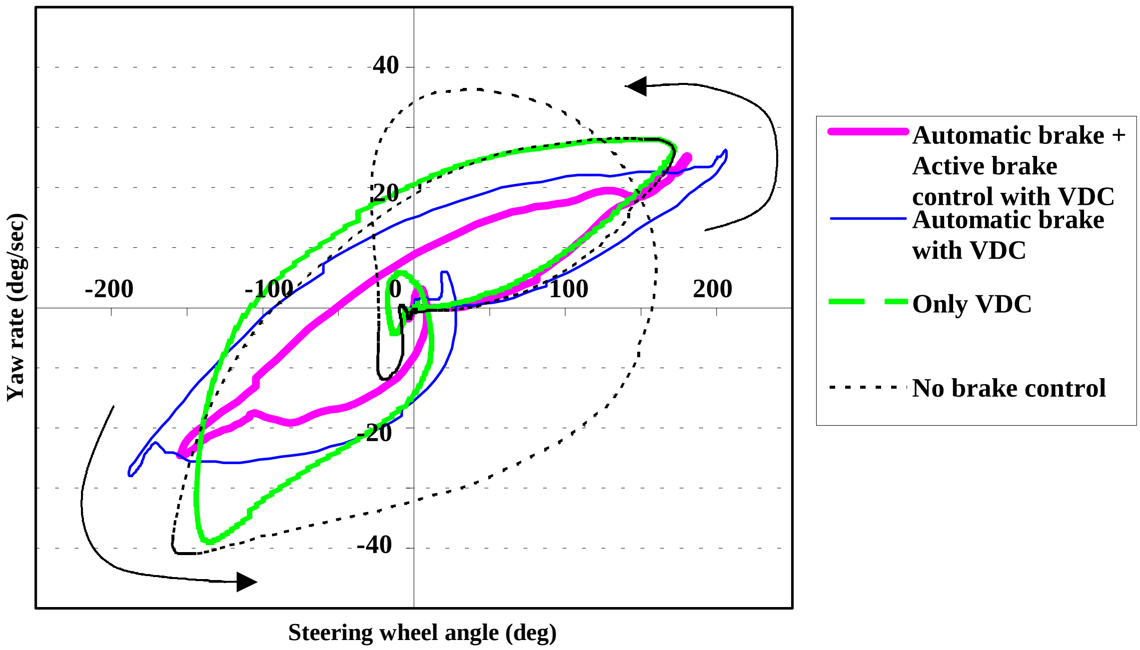


Figure 11. Experimental results for emergency maneuvering

Effectiveness of the active brake control system for emergency maneuvering

To evaluate the effectiveness of the system, an experiment was conducted as shown in Figure 10. The experimental scenario assumed here is as follows. The driver of the Nissan ASV-2 is traveling straight ahead, unaware that a vehicle is stopped on the road ahead. As the Nissan ASV-2 approaches the stopped vehicle, the active brake control system triggers a warning sound and warns the driver of potential danger by illuminating a red triangle in the head-up display in front of the driver. As a result of this warning, the driver executes an avoidance steering maneuver. In line with this scenario, the drivers who took part in the experiment were instructed to simulate inattentive driving with respect a forward obstacle while driving on a straight course. A mock-up of a stopped vehicle was used as the obstacle.

Four control conditions were defined. Under the first condition, braking force and traction were not controlled during the avoidance maneuver. This means that the vehicle had no VDC capability. The second condition was with a VDC capability only. Under the third condition, the automatic braking system for reducing collision speed with a forward obstacle was activated during the avoidance maneuver. This case assumed that both VDC and automatic braking control were provided. Under the fourth condition, both automatic braking and the active brake control system for emergency maneuvering were activated during the avoidance maneuver. Performance comparisons were made under the four conditions.

Figure 11 shows the results of the experiment. Under the first condition without VDC, the driver executed emergency steering to avoid the obstacle, after suddenly becoming aware of its existence. The result shows that the driver had to perform counter corrective steering because the vehicle skidded.

The result for the second condition with VDC capability shows that the skidding angle of the vehicle was more effectively suppressed than in the first case without VDC. However, vehicle behavior was somewhat unsteady because the control operation was initiated after the vehicle began to skid.

The result for the third condition with automatic braking control for reducing collision speed and a VDC capability shows that skidding was prevented by the effect of VDC as well as by the effect of a lower speed resulting from deceleration due to automatic braking. However, because of the braking forces acting on the front wheels, the initial steering response was degraded, with the result that the driver had to increase the steering angle for avoidance maneuvering and hold the steering angle for a longer time. In other words, it was necessary for the driver to compensate the degraded steering response of the vehicle.

The result of the fourth condition with both active automatic braking control for reducing collision speed and active brake control for emergency maneuvering shows that the latter capability compensated for the steering response. Therefore, the driver did not have to steer as much, nor hold the steering angle for the emergency maneuver for as long a time. This result indicates that the system assisted the avoidance maneuver by steering for the driver.

CONCLUSIONS

This paper has described various systems incorporated in the Nissan ASV-2 for reducing the number of traffic accidents. As examples of accident avoidance technologies, the automatic braking system for reducing collision speed, the active brake control system for emergency maneuvering and a combined system incorporating both systems were compared in terms of the ability to avoid a forward obstacle. The results confirmed that the most effective system for emergency maneuvering is the combination of the automatic braking system for reducing collision speed with the active brake control system for emergency maneuvering.

FUTURE WORK

In order to implement these ASV technologies in production vehicles, there are still a lot of issues that must be addressed. In addition to general issues such as reducing the system cost and downsizing systems for easier vehicle installation, the recognition performance of external world sensing devices must be further improved. The human-machine interface must also be optimized so that warnings are triggered and control operations are executed in ways that feel natural to drivers. The perception or acceptance of ASV technologies by drivers and society and implementation of the road infrastructure needed for interactive cooperative are other issues that must be dealt with. At Nissan, we intend to continue our efforts to resolve these issues and to commercialize our ASV technologies with the aim of achieving even safer vehicles.

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